Effectiveness of JSAF as an Open Architecture, Open Source Synthetic Environment in Defence Experimentation

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ABSTRACT

*Today's operational environment necessitates joint or combined operations at all levels. Modeling and simulation (M&S) is a key element supporting combined or joint forces experimentation, training and decision support needs. M&S has been widely used for many years by NATO nations and a considerable number of Simulation Systems have been developed for specific military needs. However, there are few joint Simulation Environments that can support current and future requirements, and that will range from low to high level of fidelity. Very few tools can support the thus far elusive concept of "**Scalable Fidelity**". We have thus tested the hypothesis that Joint Forces Command (JFCOM)'s Joint Semi Automated Forces (JSAF) has the potential for the integration of models with varying levels of fidelity, therefore making it a suitable Synthetic Environment (SE) with scalable fidelity, which is a highly desirable feature for CD&E activities. We believe this was achievable in part due to JSAF's open architecture,its reliance on open standards and being" open source" or more precisely, "government source available".*

Results indicate that JSAF's open architecture allows easy internal replacement of both low and high fidelity models. Results also show that JSAF's open architecture brings the flexibility to update the system according to CD&E specific requirements. In terms of reusing M&S developments in spiral CD&E work, JSAF seems to support the concept of "Scalable Fidelity" quite well since it supports designing or composing with the anticipated attributes of the planned future. However, a number of problems were encountered with JSAF. Some inevitable problems were related to both the lack of documentation in particular for the current version (it is the version used for MNE-4 experiments) and the implementation of the environment.

We present data from our present efforts that supports accepting our hypothesis and we conclude that JSAF as an open architecture and open source SE can be used effectively to support spiral experimentation that requires not only interoperability, but also reusability, scalable fidelity, extensibility. In this context, a JSAF knowledge base portal is needed and when our related efforts are shared with the community, this will help make JSAF a more reusable and robust platform, particularly if the scalable fidelity capability allows the models to seamlessly scale up from concept development, to experimentation material acquisition and to training.

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1.0 INTRODUCTION

The future of strategic capability has gained increased prominence in the consciousness of the DND/CF. There has been an increased focus on the issue through the publication of a number of keystone documents. 'Canadian Defence Beyond 2010-The Way Ahead' was promulgated in May 1999. A month later DND/CF published its vision for the future, 'Shaping the Future of Canadian Defence': A Strategy for 2020.

This concept paper 'Creating the CF of 2020' and the April 2000 symposium that preceded it are the direct result of way ahead paper. The Symposium, which concentrated on Concept Development and Experimentation and the integration of Modelling and Simulation (M&S). Another document released Strategic Capability Planning for the CF, advocates a new capability-based approach to force development. In order for this process to be successful, right tools must be provided to those who work in the force development domain. A robust CDE capability and integrated M&S tools are key to achieving the transformation to the DND/CF of the future. [1, 2, 3]

CDE process involves the examination of new concepts in doctrine, organization and technology required for the future forces through workshop and symposia, M&S, technology demonstrations, and computer-aided and field exercises.

A three-their approach to CDE in Canada is envisaged as shown in Figure 1.

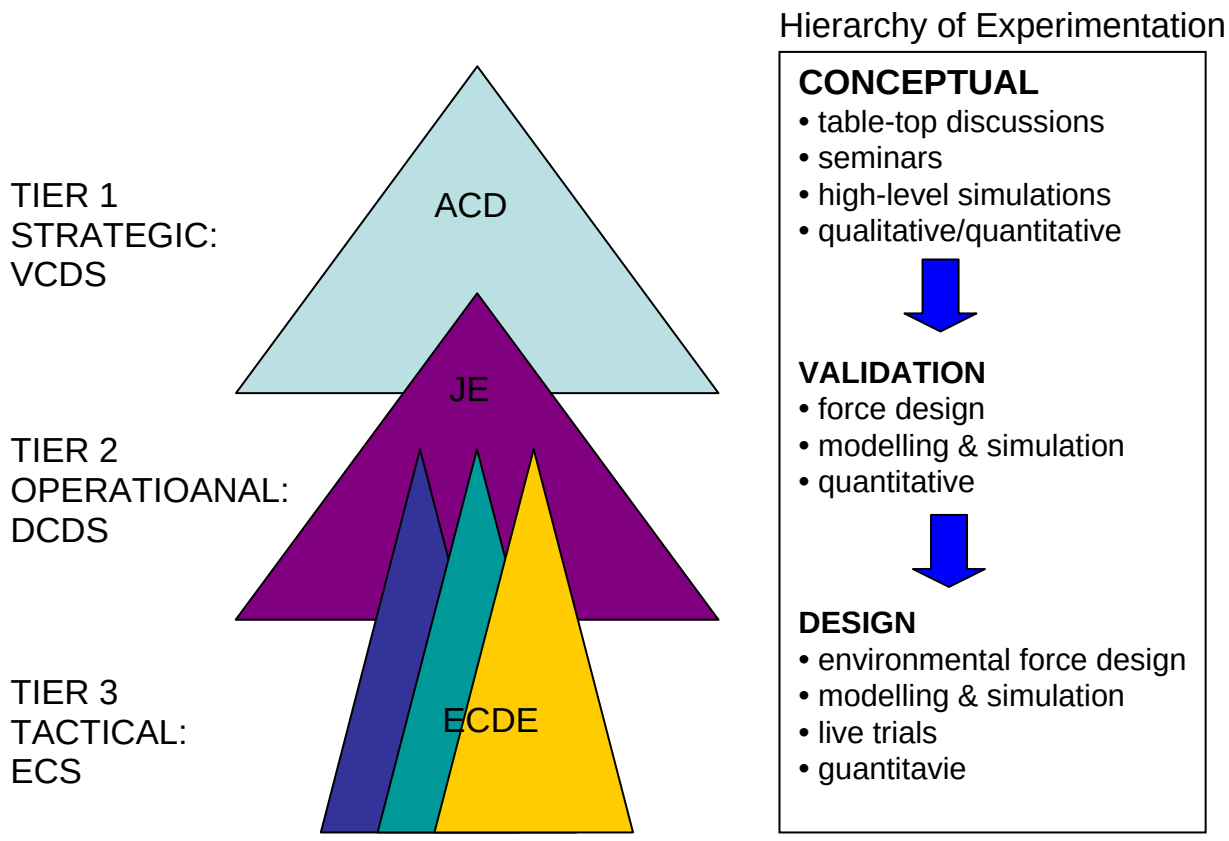

Figure 1 The Three Tier Concept

The main focus of the second their, Joint Experimentation, is experimentation with future joint capabilities, with emphasis on the mid-term 5-15 year timeframe. Additionally, it must ensure the

continued interoperability of the CF with coalition and allied partner, as well as with other departments of government, particularly in the area of doctrine and C^4I. Canadian Forces Experimentation Center (CFEC) is responsible to identify and prioritise Joint Experimentation opportunities, co-ordinate experimentation activities and establish CDE/M&S procedures, protocols and standards. Future forces Synthetic Environment Section at Defence Research Development Canada support CFEC at M&S- R&D studies.

M&S is defined as the use of models, including emulators, prototypes, simulators, and stimulators, either statically or over time, to develop data as a basis for making managerial or technical decisions. The terms "modeling" and "simulation" are often used interchangeably at DMSO M&S Glossary.

Defense modeling and simulation is a growing technology industry that provides readily available, operationally valid environments for war fighting training. In addition, it provides opportunities to train jointly, develop doctrine and tactics, formulate operational plans, and assess war fighting situations. In today's world of tight budgets, limited training ranges, and over-used equipment, M&S offers safe and innovative solutions to complex military training challenges. Its interoperability, reuse, and affordability hold the potential to revolutionize war fighting capabilities. [4] Shortly simulation is a key element for transformation and CD&E.

If you plan to use M&S at CD&E studies you have to take care of the most prominent standards like HLA and Real-time Platform Reference Federation Object Model (RPR-FOM) that helps you at interoperability issues. We will talk about the effects of the standards at CD&E M&S studies at the following paragraphs.

A common SE platform is also important for CD&E. It helps you at designing the experimentation; you don't have to deal with different environment and platform databases (platform attributes, visual models, behaviour models…), scenario files and also interoperability issues. A common SE also reduces time, budget and effort at your experiments.

To support DND/CF CDE/M&S needs, we examined effectiveness of JFCOM's JSAF as an open architecture, open source synthetic environment.

2. JSAF AS A SYNTHETIC ENVIRONMENT

Joint Semi-Automated Forces (JSAF) is a simulation system used to generate entity level units such as tanks, ships, aircraft, and individual combatants, including their associated sensor systems and munitions. The individual units are organized within appropriate command structures that may be controlled as collective units. JSAF units execute tasks and behaviours appropriate for the type of unit simulated and users may override or interrupt many of the automated behaviours [5].

JSAF provides a graphical user interface (GUI), referred to as the JSAF Plan View display (PVD), that enables operators to create, task and interact with units in a JSAF scenario. JSAF is a High Level Architecture (HLA) compliant federate that publishes battlefield states and events. JSAF has various Federation Object Models (FOMs) and an internal Simulation Object Model (SOM) that describe the objects and interactions that are published through HLA.

2.1. "Open Source" or "Government source available"

To achieve concept objectives you have to use military platforms or systems; to support concept development phase you have to make live and virtual experiments; to make good CD&E with M&S you have to represent real world and platforms or systems as good as possible. Your synthetic environment should be flexible so that you can easily modify it to support your experiment. Open source systems help you tailor it according to your needs and prevent you look for another synthetic environment for your

other experiments. JSAF is an open source environment. You can modify the entity attributes, tasks & behaviours; even it is not an easy task. Current version of the JSAF that we have doesn't have a good documentation. This was one of the difficulties we encountered while we were using the JSAF; even we have the operator and developer course it took time to understand hierarchy. JSAF (in our current version) has 1591 entity and object files. This gives a great flexibility & power to design your experiment according to your needs; by updating the entity parameters you can change characteristics of platforms or systems. You can define M1-A1 tank as improved or modernized M1-A1 tank by updating IR sensor capability. Also you can change the fidelity of the sensor this gives you a grate power also. You can apply your R&D studies on platform or systems to the experiments with the help of open source synthetic environment.

2.2. Open Architecture

When you talk about open architecture you also talk about the open standards. JSAF is a HLA compliant and FOM agile SE. In following paragraphs we talk about the HLA and FOM Agility concept, which is important for open architecture of JSAF.

2.2.1 High Level Architecture (HLA)

HLA originated to provide flexibility to develop, reuse, and connect federates into groups (federations) to satisfy a diverse set of requirements. HLA provides a standard set of distributed M&S services and data interchange formats that, with appropriate expertise, can be used to achieve interoperability amongst HLA federates. HLA was developed based on the notion that a single, monolithic, simulation cannot satisfy the needs of all simulation users. Originally mandated by US Department of Defence, HLA adoption policy (including exclusion) based on requirements, resources, component priorities, or security is now up to each US DoD Component. HLA has been in development since 1996. In September 2002, DMSO ceased to develop, distribute and support (at no cost) the DMSO RTI and users were instructed to purchase commercial versions of the RTI. HLA began as a US DoD standard and has evolved into an open standard – the Institute of Electrical and Electronic Engineers (IEEE) Standard 1516. The IEEE HLA standards consist of three main components: a set of architectural rules, an object model template (OMT) specification, and an interface specification.

The Run-Time Infrastructure (RTI) software implements the HLA interface specification and provides simulation components with a set of distributed services. A set of software Application Programmer Interfaces (APIs) provides a well-defined interface by which federates interact with an RTI.

HLA capability of JSAF lets you connect other federates to your JSAF federation. We could run JSAF federation with DMSO RTI 1.3 NG. JSAF federation can be expanded according to experiment needs. Even it is not an easy task this gives you a great power and flexibility.

2.2.2. HLA FOM/SOM Interoperability

There is a misconception that if a federation supports a particular FOM then all federates in the federation support all components described in that particular FOM. This is no longer true. The FOM enables all federates in the federation to form a common understanding of what data is available to be communicated on the HLA network and how and when that data will be made available. What information is supported by any particular federate is defined by the federation FOM and the federate's SOM and RTI interfacing code.

We used RPR-FOM 2.0 which is usually standard at JSAF federation; RPR FOM 2.0 is created from SISO standard FOM RPR FOM 1.0. With the help of RPR FOM you can easily connect other federates to your JSAF federation. It helps you

2.2.3. FOM Agility

FOM agility is the ability of a federate to readily participate in multiple federations that use different FOMs [5]. The objective of FOM agility is to build a HLA application once and to enable that HLA application to automatically, or simply, switch between different FOMs without recoding and/or recompiling applications. FOM agility is implemented in *middleware*. Figure 2 shows MaK Technologies FOM Agility implementation (in VR-Link) using a combination of a FOM independent, Middleware API (to do FOM component conversions) coupled with a FOM Mapper capability that can be switched to use different FOMs without having to modify the application code. To use a different FOM requires a FOM Mapper file to be created for each specific FOM. However the same FOM Mapper file can be used by any HLA application with the required FOM Mapper support. The FOM Mapper files could be placed in a shared library to be loaded at run-time therefore not requiring the application to be recompiled and re-linked.

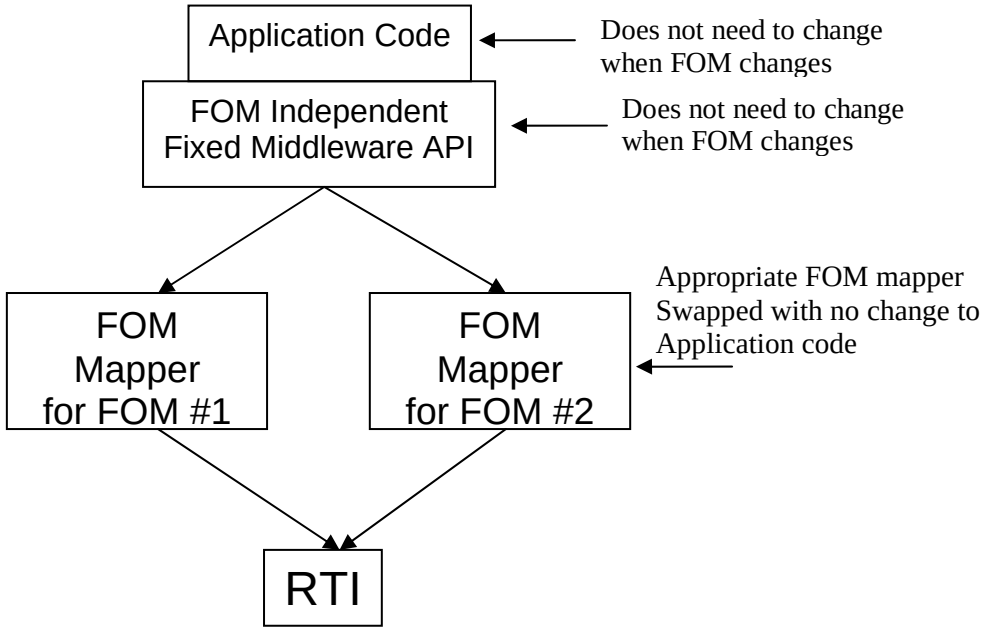

Figure 2: MaK Technologies FOM-Agility Approach.

The FOM Mapper file instructs the HLA application to do any data conversions, encoding, decoding, etc. required in order to correctly switch between FOMs without having any prior knowledge of what is defined in the FOMs. JASF has the FOM agility capability. It has Agile FOM Interface (AFI) that is why it is much easier to create a federation.

As we explained previous chapter JSAF is a open source and open architecture SE. Further to these capabilities JSAF has also support for GCCS (Global Command & Control System) and link-16 which is important to connect your SE to real world systems; and it does not have any limitation at the number of entities or the side definition (red-blue-green-white), unless you have the machine power. The last thing that is important for the JSAF ability to change fidelity. Even it is little bit problematic you have the power to change the fidelity of the entity or create a high fidelity entity federate and join to the JSAF federation.

3. CONCLUSION

JSAF is an “open source”, open architecture SE. JSAF can be used effectively to support spiral experimentation that requires not only interoperability, but also reusability, scalable fidelity, extensibility.

In this context, a JSAF knowledge base portal is needed to share lessons learned at implementation phase and updated libraries. When this evolving portal is shared with our community of practice, this portal will help make JSAF a more reusable and robust platform and also save development time, i.e.: agility for the development of other experimentations.

4. REFERENCES

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[2] Canadian Forces and Department of National Defence (1999). Shaping the Future of Canadian Defence: A Strategy for 2020. http://www.cds.forces.gc.ca/pubs/strategy2k/intro_e.asp

[3] Symposium Working Group (2000). Creating the Canadian Forces of 2020: A DND/CF Concept Paper on Concept Development and Experimentation and Modelling and Simulation. http://www.vcds.forces.gc.ca/dgsp/pubs/rep-pub/dda/symp/cde/intro_e.asp

[4] M&SBOK – Modeling and Simulation Body of Knowledge http://www.site.uottawa.ca/~oren/MSBOK/MSBOK-index.htm#2

[5] JSAF User Manual.

NATO MSG

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Defence Research and Development Canada

Recherche et développement pour la défense Canada

Canada

OUTLINE

- Paper focused on data from MALO “ACTD”
- Project Objective & Organization
- Stand-alone System (SER workstation)
- **JSAF-based HLA Simulation**
- **CF MARITIME WARFARE CTR Experimentations**
- Conclusion

Maritime Air Littoral Ops (MALO) "ACTD" Project OBJECTIVE

- **Demonstrate and validate the application of Modelling and Simulation technologies** supporting both constructive and virtual man-in-the-loop simulation and Synthetic Environments elements **to facilitate tactics and doctrine development & Maritime CD&E**

Rationale for M&S-based Tactics Studies

In order of importance, the CF Mar Warfare Ctr must use M&S to:

1. Evaluate the ability to take on **New Mission Roles** (Littoral, over land, etc)
2. Develop Tactics for **New Missions** (deployments)
3. Develop Tactics for **New Types of Equipment** (Cyclone, A-IMP, UAV)
4. Evaluate **TACNOTES**
5. **Determine/validate Requirements** for New Equipment

Project Implementation

- **Implementation:** Spiral execution plan in Four Phases, with 2 Technologies.
- **Phases:**

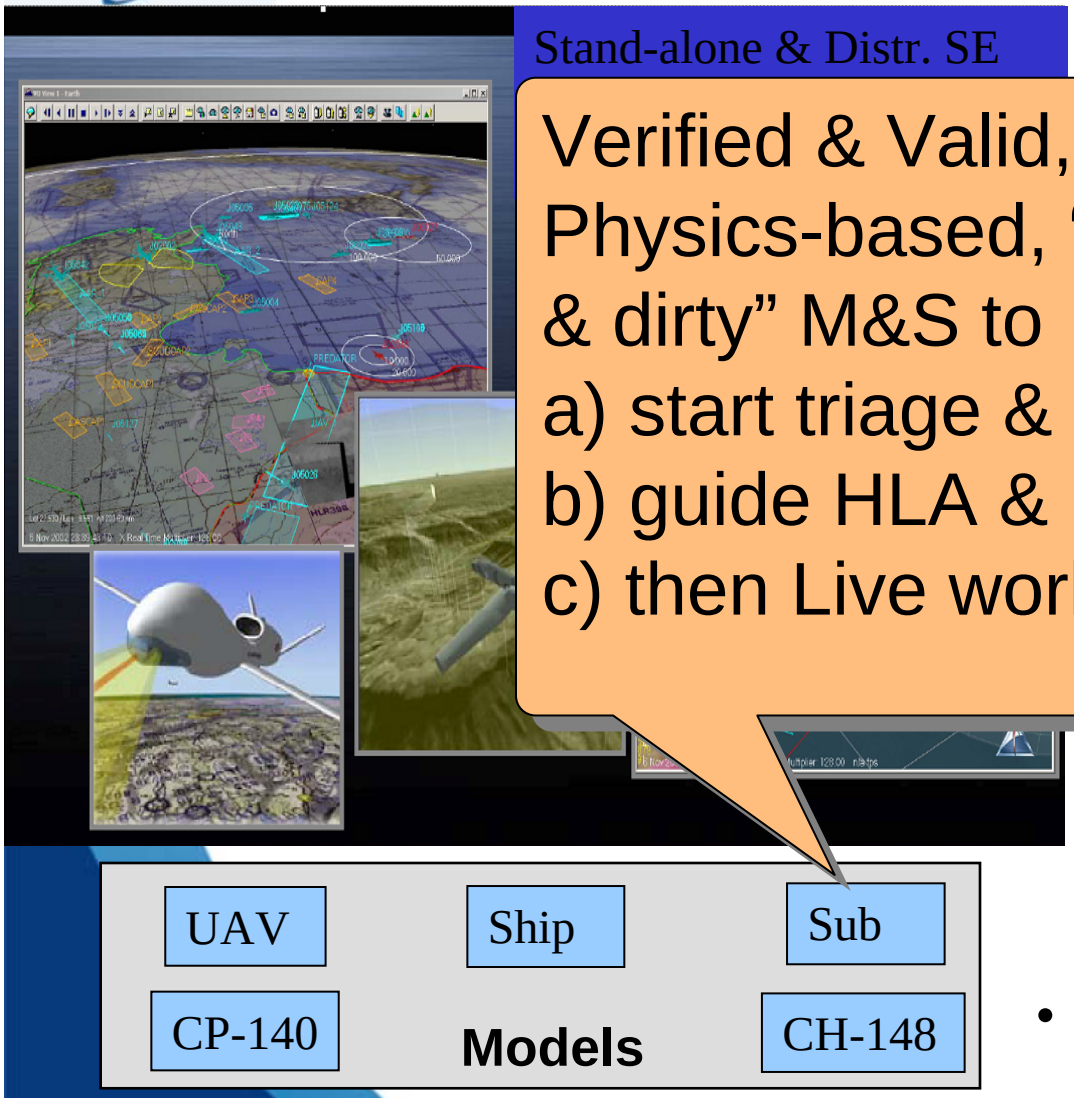
  Phase 1: MALO Stand-Alone SE Research **(SER) workstation (Tech #1)**

  Phase 2: Low-fidelity **JSAF-based HLA MALO SE (Tech #2)**

  Phase 3: Hi- fidelity HLA MALO SE

  Phase 4: HLA MALO SE Analysis System (MSEAS)

Phase I – MALO SE RESEARCH (SER) WORKSTATION



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ame technology
us Waters™) for
creation and
execution, and COTS software (STK™) for analysis and visualization.

- **Runs on 1 laptop.**

SER Simulation Engine Selection Criteria

- Single Integrated Environment
- Open Architecture and/or Open Source: Integrate external models, provide for external controls
- Standard Interface (s)
- Good Physics-Based Modeling: sensor's algorithms, platform's kinematics, entity's 3D visualization, sensor footprint, etc.
- Richness: libraries of models, terrain…
- Analytical Capability: MOE, MOP
- Robustness

SER Simulation Engine Selection: Satellite Tool Kit (STK)

- **STK's Analytical fidelity has been independently validated and verified**, and STK software has passed integration testing that is part of the Department of Defense Intelligence Information System (DODIIS) Certification Process.
- Generation of **realistic 3D animated visualizations of the coverage analysis and target acquisition** by displaying sea- , ground- ,air- and space-based objects, sensor coverage, orbit trajectories, high-resolution imagery coupled with Digital Elevation Models (DEMs) and thematic vector information, and visual cues such as lighting, position and orientation of the sun.
- Coverage analysis and visualizations for scenarios involving multiple ground targets/Areas Of Interest (AOIs), and multiple platforms with their **robust physics-based sensor models**.

SER Prototype as Demonstrated

- **Completed a scenario of a Task Force** moving to the shore, with submarines and land/FPBs SS and SA Missiles threats
- **Superposed** (Hi-Res, Georeferenced, Orthorectified) Terrain and Images Databases for 200x200 Nautical Miles East Atlantic

  ETOPO2 from Geodas (US): Underwater and Surface terrain (3D)

  ONC (Operation Navigational Charts) from NRC: Surface images
- Most of the **models within the scenario already available and integrated in STK**

  Sonobuoys models (look-up tables)

  Cookie-cutter models for ISAR and dipping sonar

⟶ Three vignettes demonstrated

⟶ What about the Distributed SE?

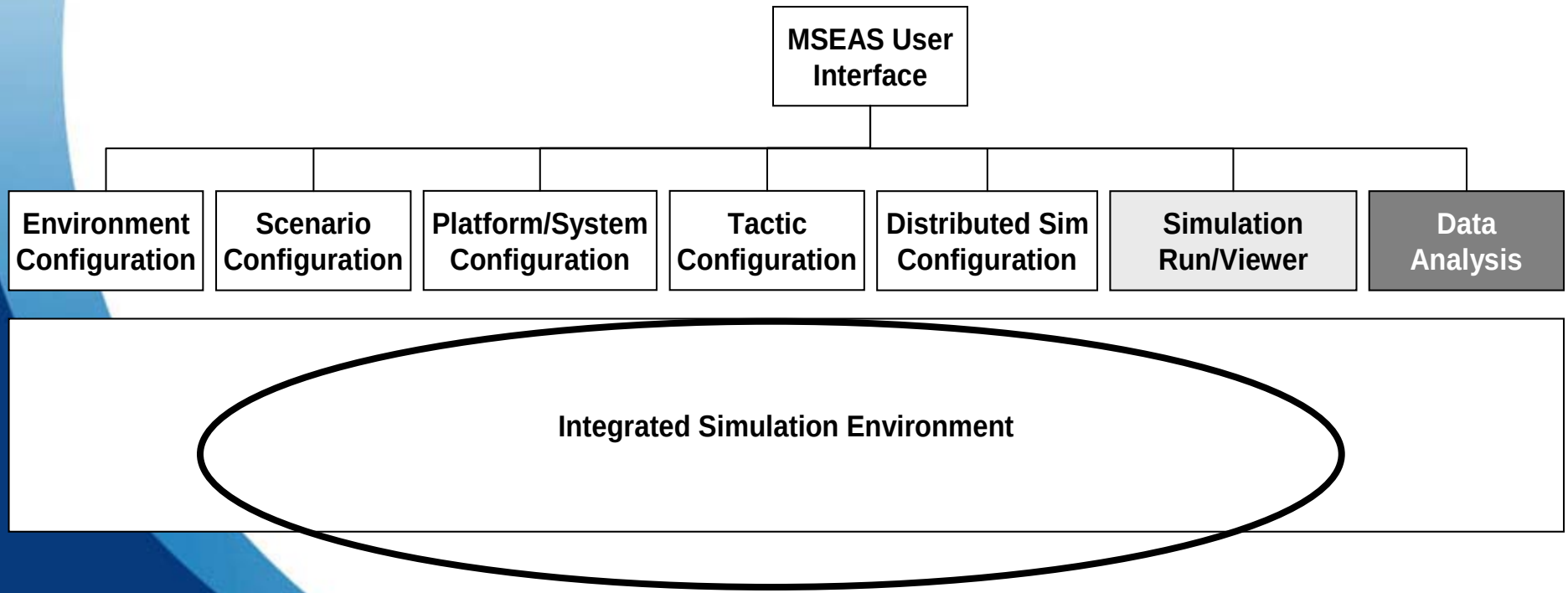
What are the MSEAS Simulation Engine Selection Criteria?

By decreasing order of importance

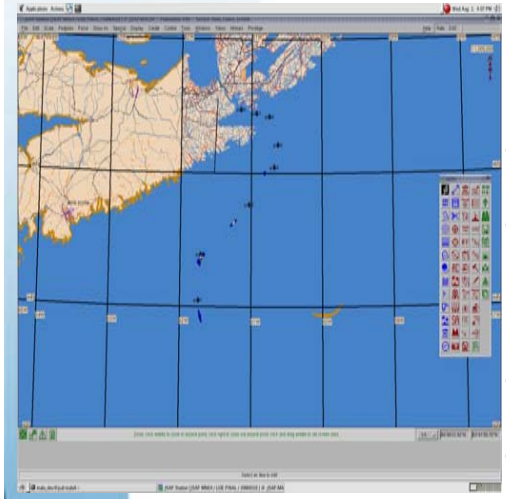
- Well Established **Computer Generated Forces** (CGF)
- Support **HLA** Protocol & other Open Intl Standards
- **Versatility in All Three Domains**: Air, Land and Sea
- **Commonality/Support** by Other DND/DoD Projects
- **Good Physics-Based Modeling: Sensor's Algorithms, Object's Kinematics, Entities' 3D visualization, Sensor's Footprint**, etc.
- **Open Architecture and/or Open Source**: Integrate external models, provide for external controls
- Standard Interface(s);
- **FOM Agility**
- Allow "**Scalable Fidelity**" which allows Extensibility
- Further requirement for: **Front-End**: User friendly implementation of Scenario & Environmental Data
- **Back End**: Analytical Capability: MOE, MOP

MSEAS Functional Requirements

Two primary layers in the MSEAS design, an operator interface layer (top layer) and a simulation system and software tool layer (bottom layer), integrated to form the MSEAS environment

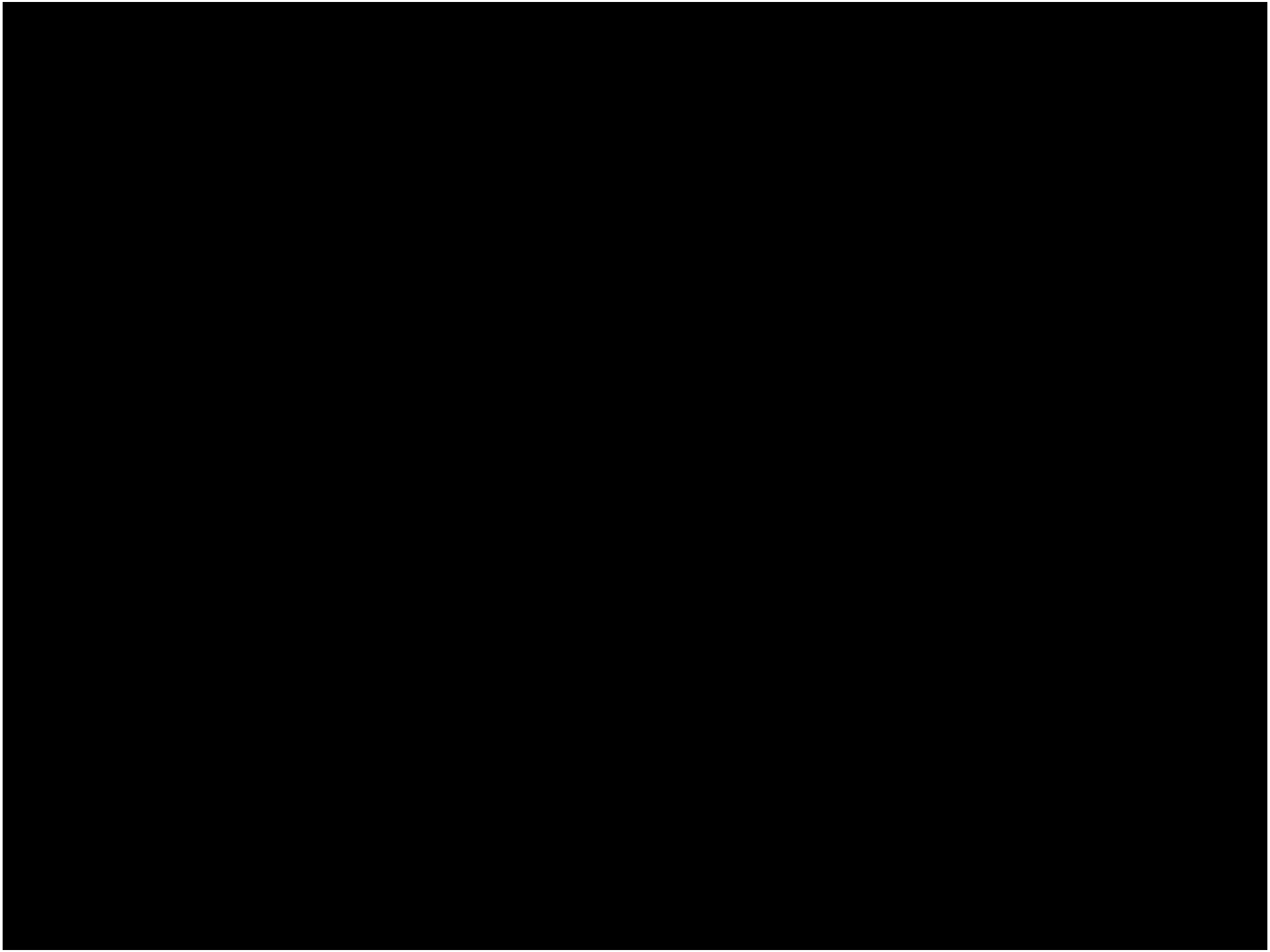


RESULTS:
Selecting JSAF as MSEAS Simulation Engine



- Joint Semi-Automated Forces is from the **US JFCOM**
- Supports **HLA & DIS (IEEE 1516 & 1278**) (+ other interfaces)
- **Selected as the Main SE by Can Air Force** CASE Proj in WIB, used by CAN "JFCOM-like" or CFEC in Multi-National Experiments (MNEx)
- **Rich Environment: Platforms, Sensors, Tasking**
- **Fine Level of Representation and Access to: Sensors** Parameters, Terrain Elements, Environmental Conditions, Platform Capabilities
- **Realistic Representation**: Entities' Capabilities and Behavior
- **Open Source** or "Govt Source Available"; **Modular**; **open Interface**
- Used by Several US DoD and US Navy Projects for Tactical Development;
- **FOM Agile, scalable**, user friendly implementation of Envir. DB (i.e: CTDB and STF)

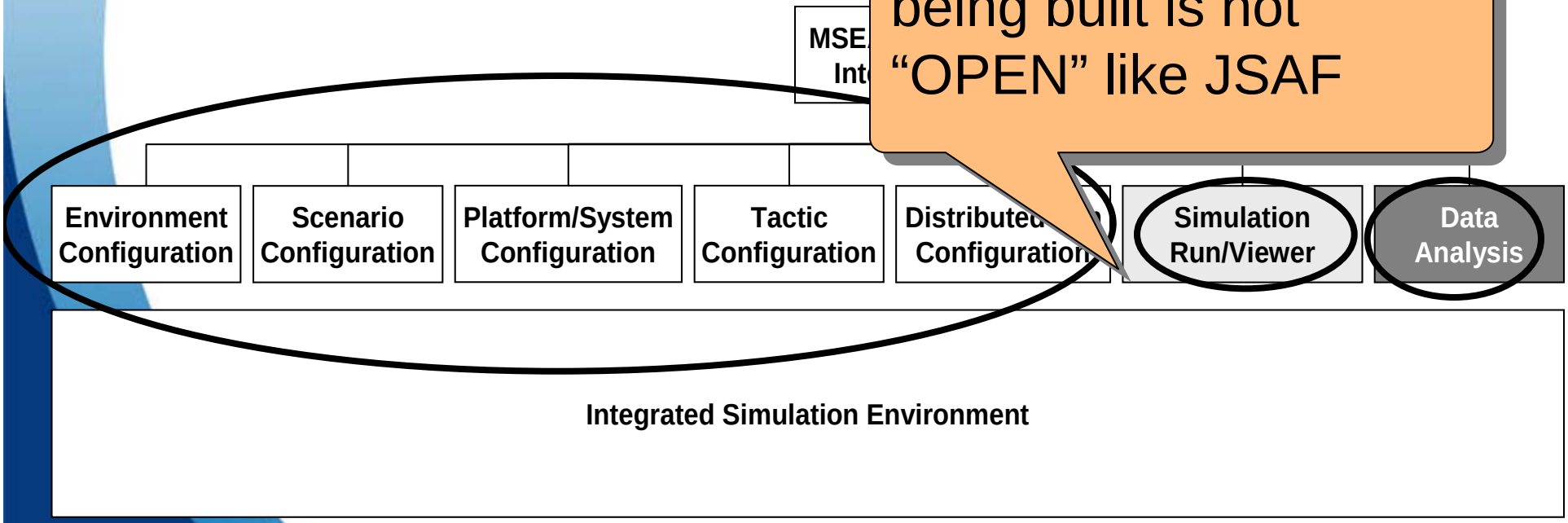
Perhaps it is best to SHOW it first !



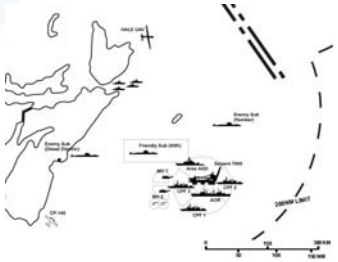
Functional Results

Two primary layers in the MSE
interface layer (top layer) and a
software tool layer (bottom laye
MSEAS environment

Much More Development time required in Front-End and Back-End, if SE being built is not "OPEN" like JSAF



Experimental Approach



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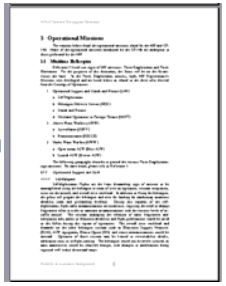

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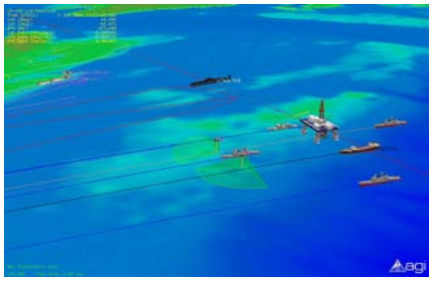
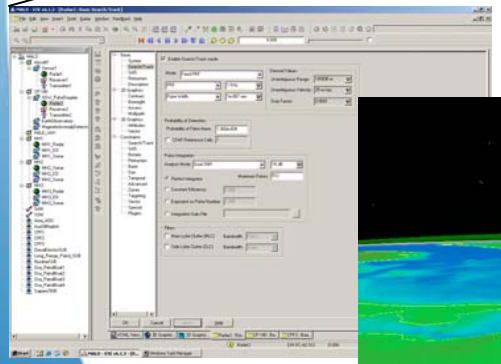
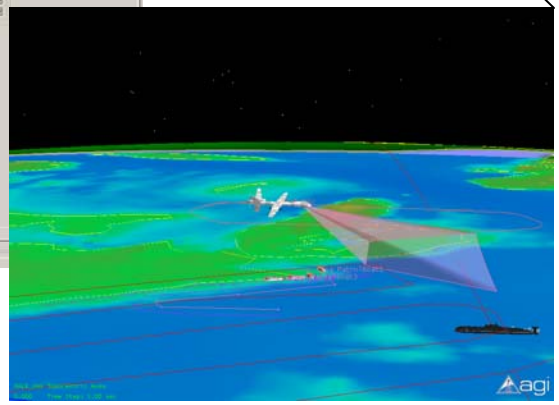


Composite Mission Scenario: Timeline and Visualization

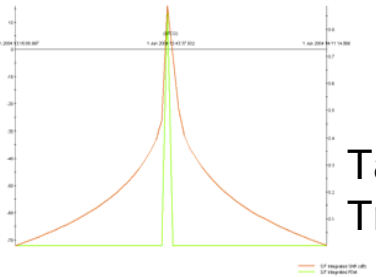
Opportunity for tactics investigation



Tactics Encoding and Modeling



Synthetic Experimentation



Data Processing

Tactics Analysis Triage

Composite Mission Scenario for study

- ASW and surveillance and targeting missions for MH and CP-140 (P3 like)
- Describes representative series of events;
- Details of mission can be altered to support development and validation of tactics and techniques
- Mission segments can be re-used in tactics analysis
- **Developed through working groups with MAC(A) and CFMWC**
- **Reviewed by "Helo Op T&E Facility" (HOTEF).**

MALO Experimentations

- **Blue**:

  -MH Tacco

  -System Operator

  -Advisor/Scribe

- **Red**:

  -Submariner

  -System Operator

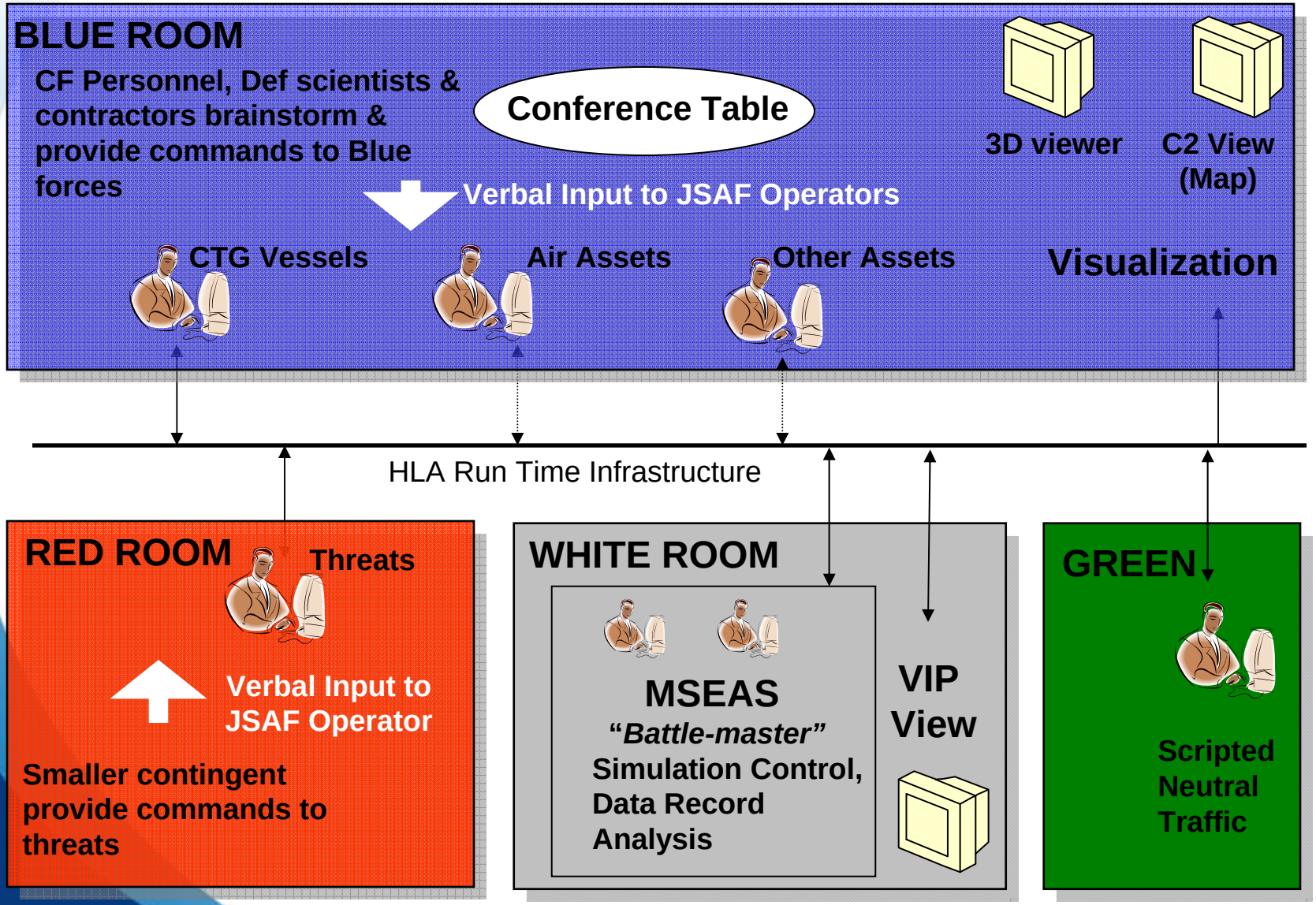
  -Advisor/Scribe:

- **White/Green**:

  -BattleMaster

  -Observers: CFMWC, MSECO, MARLANT

War Game Layout



MH Scenario: Forces and Missions

Blue:

Task Group 4 X FFG, one freighter, one container ship (**HVU** or high value unit)

One Sea King Helo

Mission:

Detect and Destroy **SSK**

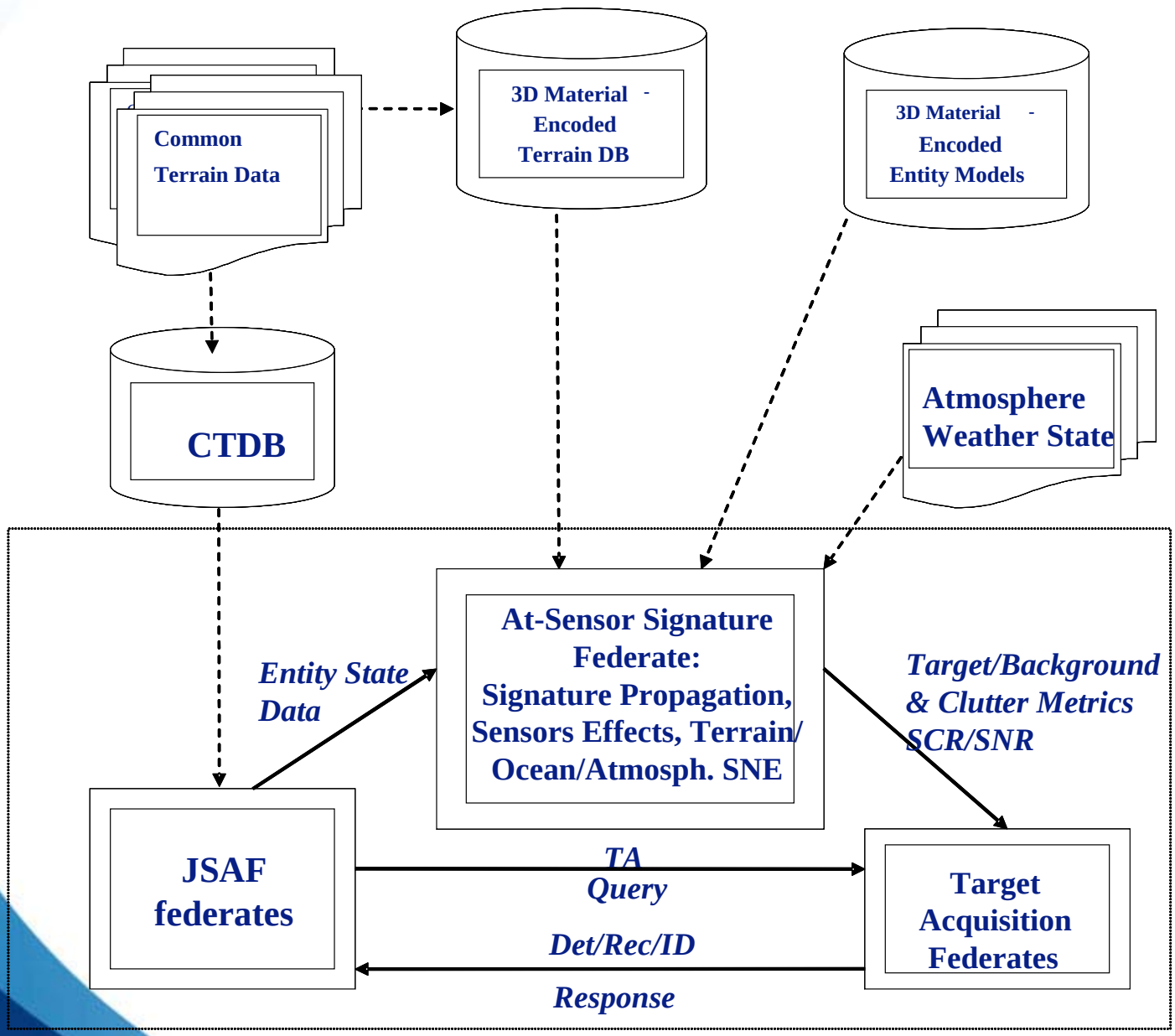
Red:

One Kilo SSK

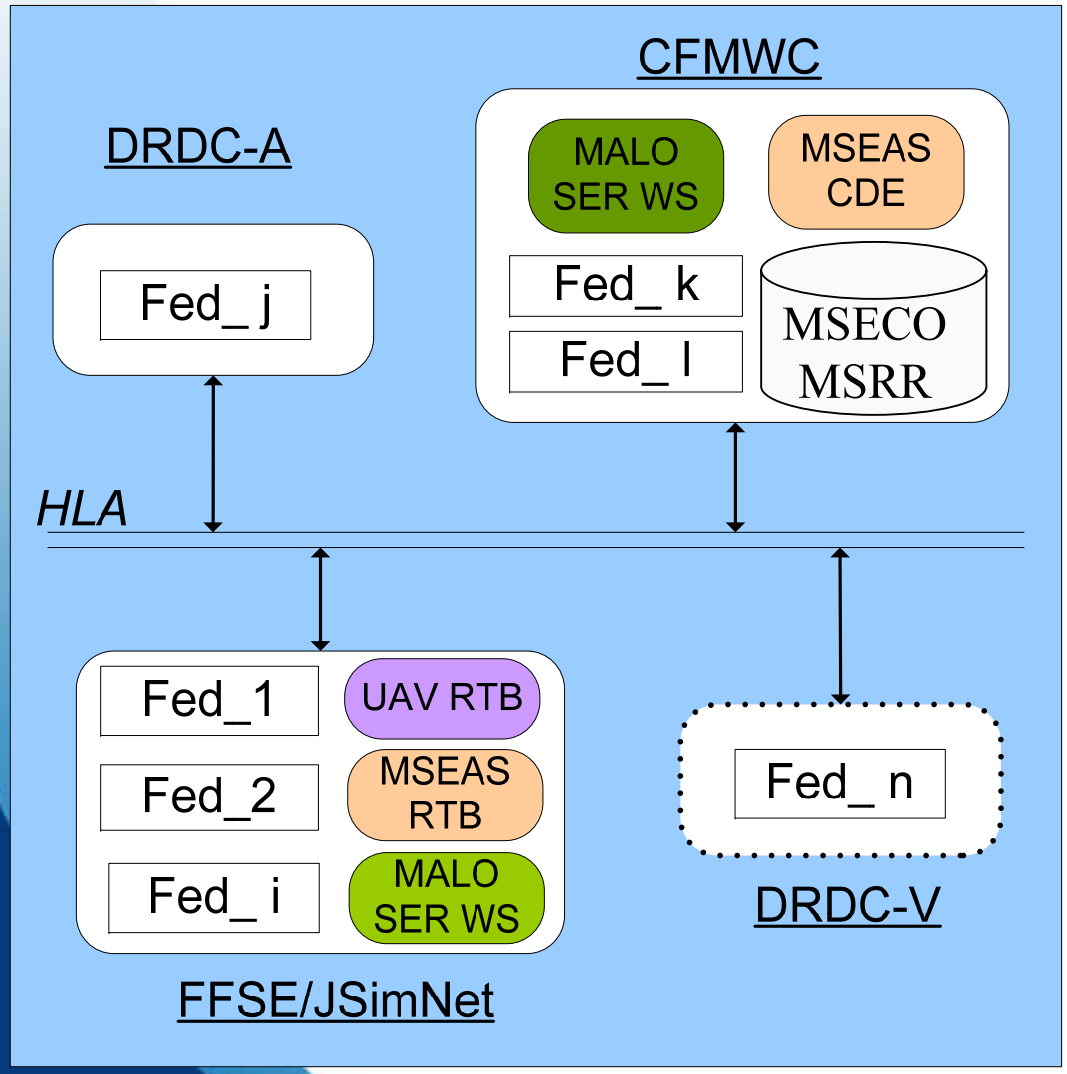
Mission:

Detect and Destroy **HVU**

Architecture of Simulation



Phase IV – HLA MALO SE ANALYSIS SYSTEM (MSEAS)



- Access to Persistent Sim Network across Labs and client's site
- Full MSEAS implementation
- Delivery to client

Conclusion: Functional Requirements

Functional requirements have been generated using the JSAF-based MSEAS concept functional groupings, whereby requirements categories include functional and technical requirements for:

- Environment Configuration
- Scenario Configuration
- Platform/System Model Configuration
- Tactic Configuration
- Physical Network Configuration
- HLA Federation Configuration
- Experimental Metric Configuration
- Simulation Run Time Monitoring
- Physical Network Monitoring
- Real Time Metric Monitoring
- Post Run Data Analysis

CONCLUSIONS

- **<u>Innovative approach to develop Synthetic Environments</u>**
- Experimental Process combines 2 technologies:
  - Standalone system (SER)
  - HLA JSAF-based SE (in MSEAS)
- MSEAS is more then a classic simulation system due to its:
  - **Rapid Scenario Gen capability in Front end**
  - **Analytical/Metrics capability in Back end;**
  - **And…effective SE**

CONCLUSIONS

- In conclusion, this study has shown that to be effective an SE should have:
  - Open source/Govt Source Avail, i.e.: like the Power of LINUX
  - Open Architecture (modularity, etc)
  - Open Intl Standards (IEEE 1516, 1278; SISO-STD-001.1-1999)
  - HLA compliance
  - FOM Agility
  - Allow "Scalable Fidelity" which allows Extensibility to grow from CD&E to MA&S, Training, Mission Rehearsal;
  - Commonality (Regional, National, International) breeds Interoperability;
  - Flexibility;
  - Documented (would be huge help for JSAF hierachy)
  - User friendly implementation of Environmental Data Bases;
  - **Open interfaces to modify front end and back end**
- **To support M&S-based NEC, & Capability Mgt, must have the right tools, the right approach across partners not only in Natl Defence but in Natl Security. It includes tools with characteristics of JSAF.**

QUESTIONS/COMMENTS?